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Additions to the mycobiota of Poland

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Abstract—One saprobic fungus (*Agyrium rufum*), one facultative lichenicolous fungus (*Trimmatostroma quercicola*), and six obligatory lichenicolous fungi (*Arthonia coronata*, *Cornutispora intermedia*, *Didymocyrtis melanelixiae*, *Minutoexcipula mariana*, *Stigmidium rivulorum*, and *Weddellomyces xanthoparmeliae*) are reported as new to Poland. *Lecanora pulicaris* is a new host for *Cornutispora intermedia* and *Ochrolechia turneri* for *Minutoexcipula mariana*. Seven of the reported species were found in natural forest communities in Białowieża National Park. Discussions on characteristics of each species and distributions are also provided.

Key words—mitosporic fungi, *Ascomycota*

Introduction

Lichens, lichenicolous fungi, and allied fungi are a reasonably well-known group of organisms in Poland (Fałtynowicz 2003, Czyżewska & Kukwa 2009). However, additional research, especially in areas with well-preserved natural forests, continue to provide new data on their occurrence, including the discovery of species new to science (Kukwa & Diederich 2005, Kukwa & Kubiak 2007, Kukwa & Flakus 2009, Zhurbenko et al 2009, Kukwa et al. 2010, 2012, 2013, Guzow-Krzemińska et al. 2016). Here we present the first Polish records of eight species of saprobic and lichenicolous fungi.

Material & methods

The material studied is deposited in KTC, LBL, and UGDA. The technical descriptions are based on Polish material, except for *Didymocyrtis melanelixiae,*

where the teleomorph was not found among our samples. The localities are presented according to the modified ATPOL grid square system (Cieśliński & Fałtynowicz 1993, Kukwa et al. 2002). For species collected in Białowieża National Park, the numeration of collecting plots follows Faliński & Mułenko (1997).

The species

Agyrium rufum (Pers.) Fr., Syst. Mycol. 2: 232. 1822.

Thallus endoxylic, non-lichenized, visible as paler patches of the substratum with scattered, minute, flat to convex, irregularly roundish, pale orange to red-brown apothecia. Exciple soon excluded, but visible in young apothecia, consisting of branched and anastomosing hyphae, pale to deep orange-brown in section, K+ orange-red. Hymenium 70–80 µm thick, intensely I+ blue, K+ orange-red. Paraphyses branched and anastomosing. Asci broadly clavate, of *Trapelia*-type, 8-spored. Ascospores simple, hyaline, 10–12 × (4.5–)5–5.5 µm.

Ecology—In Poland *A. rufum* was found only in Białowieża National Park (NE Poland) in two localities in natural pine-oak mixed forest growing together with *Micarea soralifera* Guz.-Krzemiń. et al. and other *Micarea* species on decorticated logs. It is perhaps more common in Poland, but due to the small size of apothecia easily overlooked in the field.

Specimens examined—**POLAND. North Podlasie District**, Bielska Plain, Białowieża National Park, forest unit no 256, plot G03, 52°46′02″N 23°51′48″E, ATPOL grid square Cg–55, *Pino-Quercetum*, on decorticated log, 05.2015, M. Kukwa 15930, A. Łubek (KTC, UGDA); plot G04, 52°46′02″N 23°51′53″E, *Pino-Quercetum*, on decorticated log, 05.2015, M. Kukwa 15939, A. Łubek (KTC).

Comments— For a detailed description see also Dobson et al. (2009).

This is a non-lichenized, saprobic fungus that is superficially similar to *Micarea* species with dark apothecia (e.g., *M. denigrata* (Fr.) Hedl. and *M. misella* (Nyl.) Hedl.). *Agyrium rufum* is readily distinguished by its *Trapelia*-type asci and the lack of photobiont in the thallus (Dobson et al. 2009).

Molecular phylogenetic analyses have shown that *A. rufum* is closely related to *Pertusaria* DC. s. str., from which it is easily morphologically distinguished by its much smaller apothecia and *Trapelia*-type asci (Hodkinson & Lendemer 2011).

Agyrium rufum has been found in many European countries growing on wood of diverse woody plants in various forest ecosystems (e.g., Coppins & Coppins 2006, Dobson et al. 2009, Mihál et al. 2012, Malíček & Palice 2013, Spribille et al. 2014). The species has also been found in Australia (Kantvilas 2002).

Arthonia coronata Etayo, Bull. Soc. Linn. Provence 47: 95. 1996.

Ascomata formed on discoloured parts of the host thalli, black, convex, usually covered with simple, dark, <25 μm long hairs giving the surface a roughened appearance. Hymenium and hypothecium hyaline. Ascospores 1-septate, 10–13 × 3.5–4 μm, hyaline at first, becoming pale brown with age.

Ecology—In Poland *A. coronata* was recorded in Białowieża National Park where it is found on podetia of sorediate *Cladonia* species growing on wood and bark of logs and stumps in pine-oak mixed forest and fresh (spruce)-pine forest.

Specimens examined—**POLAND. North Podlasie District**, Bielsk Plain, Białowieża National Park, ATPOL grid square Cg–55, forest unit no 256, plot E09, 52°45′55"N 23°52′20"E, *Pino-Quercetum*, on *Cladonia subulata*, on stump, 08.2015, A. Łubek (KTC); plot G01, 52°46′02″N 23°51′37″E, *Pino-Quercetum*, on *C. coniocraea* growing on stump, 05.2015, M. Kukwa 15918, A. Łubek (KTC); plot G04, 52°46′02″N 23°51′53″E, *Pino-Quercetum*, on *C. grayi* growing on bark of log, 05.2015, M. Kukwa 15897, A. Łubek (KTC) and *C. digitata* growing on decorticated log, 05.2015, A. Łubek (KTC); plot H04, 52°46′05″N 23°51′53″E *Peucedano-Pinetum*, on *C. grayi* and *C. coniocraea* growing on decorticated log, 05.2014, M. Kukwa 13592, A. Łubek (KTC, UGDA); plot L07, *Querco-Piceetum*, on *C. grayi* growing on decorticated log, 29.09.2015, M. Kukwa 17540a, A Łubek (UGDA); plot M01, 52°46′18″N 23°51′37″E, *Peucedano-Pinetum*, on *C. grayi* growing on wood of log, 05.2015, A. Łubek (KTC).

Comments—For descriptions see also Etayo (1996) and Coppins & Aptroot (2009).

Arthonia coronata is distinguished by its black and convex ascomata with usually simple dark hairs (best visible in apothecial section under the microscope) giving the ascomata a roughened appearance, and the 1-septate hyaline ascospores that become pale brown with age, ascospores. It cannot be with confused with any other lichenicolous fungi inhabiting *Cladonia* thalli (Etayo 1996).

The species was first found in France and Spain on soralia of *Flavoparmelia caperata* (L.) Hale but later was also recorded from other countries on thalli of *Cladonia* species. The presence of the fungus is manifested by a discolouration of the host thallus by black ascomata (Etayo 1996, Coppins & Aptroot 2009, Diederich et al. 2012).

Arthonia coronata has been found in Africa (Canary Islands), North America, and Europe (Austria, Belarus, Belgium, France, Germany, Great Britain, Italy, Luxemburg, Portugal, Spain, Sweden) (Etayo 1996, Coppins & Aptroot 2009, Diederich et al. 2012, Boom 2013, Svensson et al. 2013, Roux et al. 2016, Tsurykau et al. 2016).

Cornutispora intermedia Punith. & D. Hawksw., Mycol. Res. 107: 920. 2003.

Anamorph—This species is known only in the anamorphic state, which causes discolourations of host thalli. Pycnidia scattered, immersed or with upper parts exposed over the host thallus, globose with pseudoparenchymatous walls, pale brown to dark brown, c. 150–160 µm in diam. Conidia holoblastic, hyaline, tri-radiate; main axes 9–12 µm high (from the truncate bases to a point where the conidia branch) and 2–2.5 µm wide; divergent arms 3–5 × 2–2.5 µm, with swollen bases. Both axes and arms end with narrow, 3–5 µm long, tubular structures or apical appendages.

Ecology—In Poland the species was found in one locality in Białowieża National Park on the thallus of *Lecanora pulicaris* (Pers.) Ach. in a pine-oak mixed forest; *L. pulicaris* is a new host lichen for this fungus.

Specimen examined—**POLAND. North Podlasie District**, Bielsk Plain, Białowieża Forest, Białowieża National Park, ATPOL grid square Cg–55, forest unit no 256, plot D03, *Pino-Quercetum*, on *Lecanora pulicaris* growing on bark of twigs of fallen *Picea abies*, May 2015, A. Łubek s.n. (KTC).

Comments—For a full description of *C. intermedia*, see also Punithalingam (2003).

Cornutispora intermedia is the third species of the genus reported from Poland, the others being *C. ciliata* Kalb and *C. lichenicola* D. Hawksw. & B. Sutton (Kukwa & Flakus 2009, Kukwa et al. 2013). In *C. ciliata* the main conidial axes are shorter (usually 6.5–9 µm long; in *C. intermedia* 8–11 µm) and the bases of the divergent arms are bulbous (only swollen in *C. intermedia*). *Cornutispora lichenicola* has narrower main conidial axes (<2 µm wide; in *C. intermedia* >2 µm) (Punithalingam 2003).

Cornutispora limaciformis Piroz. and *C. pittii* D. Hawksw. & Punith. produce conidia of very similar in shape to those in *C. intermedia*, but the main conidial axes are >13 µm long in *C. limaciformis* and <3.5 µm in *C. pittii*. In addition, *C. limaciformis* is a non-lichenicolous fungus growing on apothecia of *Therrya fuckelii* (Rehm) Kujala (Punithalingam 2003); neither of these species has yet been found in Poland.

Cornutispora intermedia has also been reported from Europe (Germany, Italy, Peru) and USA on thalli of *Lecanora chlarotera* Nyl., *Ochrolechia* sp., *Phaeophyscia orbicularis* (Neck.) Moberg, *Physcia* sp., *Thamnolia vermicularis* (Sw.) Schaer., *Xanthoria parietina* (L.) Th. Fr., and *X. polycarpa* (Hoffm.) Rieber (Punithalingam 2003, Brackel 2009, 2014, Etayo 2010, Schiefelbein et al. 2014).

Didymocyrtis melanelixiae (Brackel) Diederich, Harris & Etayo, Fungal Div. 74: 74. 2015.

Anamorph causing discolourations of the host thalli. Pycnidia immersed in the host thallus, <90 µm diam., macroscopically black; walls pseudoparenchymatous, brown (darker around ostiola). Conidia broadly ellipsoidal, rounded at both ends, smooth-walled, hyaline, with one large (rarely two smaller) guttule, 4.5–5 × 3.5 µm. Sexual stage not found.

Ecology—In Poland the species has been found only at one locality in southern Poland on thalli of *Parmelia sulcata* Taylor.

Specimens examined—**POLAND.** Roztocze Środkowe, Roztoczański National Park, Florianka settlement, 50°33′25"N 22°59′15"E, alt. c. 250 m, ATPOL grid square Fg–01, on *Parmelia sulcata* growing on wooden fence, 17.09.2015, M. Kukwa 17532 (LBL, UGDA).

Comments—Only the anamorphic state was seen in the Polish material; according to Ertz et al. (2015) ascomata are perithecial, the hamathecium consists of paraphysoids, and asci are 8-spored. Ascospores are usually 2-septate, slightly constricted at the septa, brown, verruculose, 11.5–15 × 4–5.5 µm. For full descriptions see also Brackel (2011) and Ertz et al. (2015).

Didymocyrtis melanelixiae in its anamorphic state can be confused with four other species producing simple hyaline conidia and growing on lichens of *Parmeliaceae*. The most common species, *Briancoppinsia cytospora* (Vouaux) Diederich et al., differs in its larger conidia (5–7 × 1.5–2 µm). *Phoma melanohaleicola* D. Hawksw. & Earl.-Benn. develops pycnidia with seta-like hyphae rising from the walls and does not damage the host thallus. In *P. everniae* D. Hawksw. the conidia measure 4.5–5.5 × 1–1.5 µm, whereas in *P. dubia* (Linds.) Sacc. & Trotter they are 3.5–5 × 1.5–2 µm (Hawksworth & Cole 2004, Brackel 2011). Neither *P. everniae* nor *P. dubia* has been found in Poland.

Didymocyrtis melanelixiae is widespread, being recorded from Europe (Austria, Belgium, France, Great Britain, Italy, Spain, Switzerland), North America (Canada, USA), South America (Ecuador), and La Reunion, always on members of *Parmeliaceae* Eschw. (Brackel 2011, Ertz et al. 2015, Hafellner 2015).

Minutoexcipula mariana V. Atienza, Biblioth. Lichenol. 82: 142. 2002.

Conidiomata sporodochia-like, concave at first, but later becoming confluent and convoluted. Exciple distinct, thin, pseudoparenchymatic. Conidiophores mostly unbranched, macronematous, conidiogenous cells almost hyaline, 5–6 × 1.5–2 µm with ≤3 annellations. Conidia 6–7 µm long, brown, 1-septate, holoblastic, acrogenous, smooth-walled, with truncate bases.

Ecology—Collected from the thallus of *Ochrolechia turneri* (Sm.) Hasselrot growing on a fallen tree in a humid streamside within a black alder-ash forest in Białowieża National Park. It is the first record of *Minutoexcipula mariana* on an *Ochrolechia* species. As *Lepra*, *Ochrolechia*, and *Pertusaria* are very closely related (Schmitt & Lumbsch 2004), we consider this host range extension of understandable.

Specimens examined—**POLAND. North Podlasie District**, Bielsk Plain, Białowieża National Park, forest unit no 256, plot O02, 52°46′24″N 23°51′42″E, ATPOL grid square Cg–55, *Circaeo-Alnetum*, on *Ochrolechia turneri* growing on bark of fallen *Fraxinus excelsior*, 10.2014, M. Kukwa 13086, A Łubek (KTC, UGDA).

Comments—For descriptions see also Atienza (2002) and Diederich (2003).

Minutoexcipula mariana can be confused with two other species growing on members of *Pertusariales: M. tuckerae* V. Atienza & D. Hawksw. and *M. tuerkii* Hafellner. *Minutoexcipula tuckerae* differs in its convex conidiomata and 2–3-branched conidiophores, whereas *M. tuerkii* has larger conidia and does not develop conidiophores (Atienza 2002, Diederich 2003). *Minutoexcipula tuerkii* was reported from Poland by Kukwa & Flakus (2009).

Two *Lichenodiplis* species, *L. pertusariicola* (Nyl.) Diederich and *L. hawksworthii* F. Berger & Diederich, are also similar, but both produce closed conidiomata; additionally *L. pertusariicola* has aseptate conidia whereas *L. hawksworthii* has larger conidia (8.5–13 × 5.5–5.5 µm) (Diederich 2003). Of these two, only *L. pertusariicola* has been recorded in Poland (Czyżewska & Kukwa 2009).

Minutoexcipula mariana has previously been recorded in Asia (Japan, as *M.* cf. *mariana*), Europe (Germany, Iceland, Italy, Portugal Spain, the Azores), North America (Canada, USA, Mexico), and New Caledonia and only on *Lepra* and *Pertusaria* species: *L. albescens* (Huds.) Hafellner, *P. glomerata* (Ach.) Schaer., *P. heterochroa* (Müll. Arg.) Erichsen, *P. pluripuncta* Nyl., *P. xanthodes* Müll. Arg., and unidentified *Pertusaria* sp. (Atienza 2002, Diederich 2003, Zhurbenko 2013, Brackel 2014, Zhurbenko et al. 2015).

Stigmidium rivulorum (Kernst.) Cl. Roux & Nav.-Ros.,
Bull. Soc. Linn. Provence 44: 449. 1994.

Ascomata numerous, ≤65 µm diam., globose to subglobose. Paraphyses absent; periphyses present around ostiola. Asci 8-spored. Ascospores 1-septate, hyaline, upper cell slightly wider and shorter than lower, 13.5–15 × 4–5 µm.

Ecology—Collected in a small water spring in a shaded forest in northern Poland. The species is perhaps more widespread, but due to the small dimensions of perithecia it is easily overlooked.

Specimen examined—**POLAND. Gdańsk Pomerania**, Wysoczyzna Żarnowiecka, Pużyckie Łęgi nature reserve, 54°38′N 17°51′E, ATPOL grid square A3c–54, a small water spring in *Circaeo-Alnetum*, on *Verrucaria hydrophila* growing on pebble, 12.08.2015, M. Kukwa 17069b (UGDA).

Comments—For full descriptions, consult Roux & Navarro-Rosinés (1994), Molitor & Diederich (1997), and Zhurbenko & Hafellner (1999).

Stigmidium rivulorum is confined to freshwater *Verrucaria* and *Staurothele* species. Three other *Stigmidium* species also grow on *Verrucariaceae* Eschw.: *S. clauzadei* Cl. Roux & Nav.-Ros. has larger ascomata (80–130 × 65–120 µm) and wider ascospores (5–6.5 µm) and grows on non-aquatic *Verrucaria* species (Roux & Navarro-Rosinés 1994); *S. marinum* (Deakin) Swinscow is parasitic on marine *Verrucaria* growing on seashores and produces larger ascomata (Swinscow 1965); and *S. tetrasporum* Etayo has 4-spored asci and wider ascomata (80–150 µm diam.), and was found on a sterile thallus probably belonging to *Verrucariaceae* (Etayo 1994). Previously only *S. clauzadei* had been found in Poland (Czyżewska & Kukwa 2009).

Stigmidium rivulorum has been found in Europe (Austria, Denmark: Faroe Islands, Germany, Great Britain, Italy, Luxembourg) and Asia (Russia: Siberia, South Korea) on thalli of *Verrucaria aquatilis* Mudd and other freshwater species of *Verrucaria* Schrad. and *Staurothele* Norm. (Alstrup et al. 1994, Molitor & Diederich 1997, Coppins & Coppins 1999, Zhurbenko & Hafellner 1999, Thüs & Dornes 2003, Orange et al. 2009, Brackel 2014, Berger & Türk 2015, Kondratyuk et al. 2015).

Trimmatostroma quercicola Diederich, U. Braun & Heuchert, Bull. Soc. Nat. Luxemb. 111: 52. 2010.

Hyphomycete facultative lichenicolous, growing on oak bark, often overgrowing degenerate crustose lichen thalli or corticolous algae. Colonies an irregular net of blackish hyphae that are effuse, loose to dense, black, formed by short, often agglomerated, irregular and branched conidial chains. Conidia in simple or branched chains, globose to oblong, ≤4-septate (usually 3-septate), reddish-brown in H_2O, olivaceous-brown in K, ≤10 µm wide, with <2 µm thick, rugose-rimulose to verrucose walls.

Ecology—In Poland *Trimmatostroma quercicola* was found on the bark of old oak in moist oak-spruce forest in Białowieża National Park. It is probably widespread but overlooked due to the inconspicuous thalli.

Specimens examined—**POLAND. North Podlasie District**, Bielsk Plain, Białowieża National Park, forest unit no 256, plot E07, 52°45′55″N 23°52′10″E, ATPOL grid square Cg–55, *Querco-Piceetum*, on degenerated lichen thalli growing on bark of *Quercus robur*, 08.2014, M. Kukwa 14117 (KTC, UGDA).

Comments—For a complete description see also Diederich et al. (2010).

In general *T. quercicola* produces much thicker conidial chains than the other *Trimmatostroma* species, which are easily visible under stereomicroscope as an irregular blackish hyphal net. It also differs from *T. lecanoricola* Diederich et al. by its orange-brown, K+ olivaceous conidia, and from *T. dendrographae* Diederich et al. in producing brown conidia (without a distinct olivaceous tinge). In *T. hierrense* Diederich & Ertz the conidia often have darker outer walls on one side, whereas in *T. glebarum* Brackel conidia are 0–pluri-septate with cracking outermost wall layers, and colonies formed of hyphae developing a visible dark net on or near the surface of *Flavoparmelia caperata* thallus (Diederich et al. 2010, Brackel 2015). *Trimmatostroma cetrariae* Brackel has usually 1-septate conidia (Zhurbenko & Brackel 2013), *T. umbilicariicola* Heuchert & U. Braun develops multicellular and muriform segments in the fertile threads, and conidia of *T. varicellariae* Heuchert & U. Braun are dark brown to black (colour not changing in K) (Heuchert & Braun 2014).

The habit of *T. quercicola* (and also other lichenicolous *Trimmatostroma* species) is similar to *Intralichen* spp., which differ by having smooth-walled, paler, mostly 0–2-septate conidia and conidiophores usually that are completely immersed in the host thalli or apothecia (Diederich et al. 2010). *Taeniolella* species can be distinguished by conidia formed in acropetal chains and semi-macronematous, superficial conidiophores; multicellular aggregations of conidial cells are also absent in *Taeniolella* but are common in *Trimmatostroma* species (Diederich et al. 2010).

This recently described species is known from Luxembourg and Belgium (Diederich et al. 2012).

Weddellomyces xanthoparmeliae Calat. & Nav.-Ros., Mycotaxon 69: 505. 1998.

Ascomata black, perithecioid, scattered in the host thallus, which is discoloured where infected. Perithecia arising singly or in small groups, at first immersed, but later becoming partly exposed over the host thallus. Ascomatal wall formed of cephalothecioid plates. Asci 8-spored. Hamathecium of branched and anastomosing hyphae, ascospores are (1–)3-septate, brown, finely granulose, 25–30 × 8–10 µm.

Ecology—Found on the thallus of *X. conspersa* in the Sudety Mts, Poland.

Specimen examined—**POLAND. Sudety Mts**, Góry Sowie mts, near Jugów village, 50°38′51″N 16°30′19″E, elev. 720 m, ATPOL grid square Eb–95, on *Xanthoparmelia conspersa* growing on rock, 08.2015, E. Ossowska s.n. (UGDA).

Comments—For other descriptions see also Calatayud & Navarro-Rosinés (1998) and Kocourková (1999).

Weddellomyces xanthoparmeliae is easily recognizable by its formation of orange necrotic spots on the host thalli, an ascomatal wall formed of cephalothecioid plates, usually 8-spored asci, and brown finely granulose (1–)3-septate ascospores measuring 25–30 × 8–10 µm. It differs from all other *Weddellomyces* species in its smaller ascospores and host selection (Calatayud & Navarro-Rosinés 1998). Other lichenicolous fungi with closed ascomata growing on *Xanthoparmelia* species include *Stigmidium neofusceliae* Calat. & Triebel, *S. xanthoparmeliarum* Hafellner, and *Lichenostigma cosmopolites* Hafellner & Calat. (all distinguished by 1-septate ascospores), and *Roselliniella atlantica* Matzer & Hafellner, which produces larger and usually aseptate ascospores (Matzer & Hafellner 1990, Hafellner 1994, Calatayud & Triebel 1999, Hafellner & Calatayud 1999).

So far *W. xanthoparmeliae* is known from Europe (Czech Republic, Germany, Spain) and North America. Hosts are usually *Xanthoparmelia* species containing usnic acid: *X. conspersa* (Ehrh. ex Ach.) Hale, *X. mexicana* (Gyeln.) Hale, *X.* cf. *protomatrae* (Gyeln.) Hale, and *X. somloensis* (Gyeln.) Hale (Calatayud & Navarro-Rosinés 1998, Kocourková 1999, Brackel 2007, Kocourková & Knudsen 2011), but Brackel (2014) reported it from thalli of brown *X. verruculifera* (Nyl.) O. Blanco et al.

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